Open Access

J. Food Proc. & Nutr. Res., 2025, 2(2):139-143
ISSN (Online): 3078-9133; ISSN (Print):3078-9125
DOI: https://doi.org/10.22194/ JFPNR /25.1026
https://societyfia.org/journal/JFPNR

Society for Innovative Agriculture

Phytochemical Extracts and Essential Oils of Rosemary: Exploring Its Antioxidant, Anti-Inflammatory and Nutritional Potentials

Aqsa Hassan Khawaja*, Rai Muhammad Amir, Muhammad Tauseef Azam, Asia Latif, Abdus Samee, Salma Razzaq, Zunaira Zahoor, Mawara Nasir, Fareeha Anwar, Shazmina Hassan and Hjara Afzal Saleemi

Institute of Food & Nutritional Sciences, PMAS Arid Agriculture University, Rawalpindi Pakistan.
*Corresponding author's e-mail: ah.khawaja1911@gmail.com

Rosmarinus officinalis L. (family *Lamiaceae*), widely recognized as rosemary, is a perennial aromatic shrub originally native to the Mediterranean region and now cultivated across diverse regions, including Europe, Asia, and Africa. Traditionally, rosemary has been valued as a culinary herb, while modern applications extend to the use of its extracts as natural preservatives and therapeutic agents that enhance both the sensory quality and functional properties of food. Current research has highlighted its potential in improving food quality and extended shelf life as well as managing various health conditions such as, obesity, diabetes, inflammatory disorders, and certain neurological conditions. With increasing consumer demand for natural foods that are, additive-free foods, free of synthetic additives, attention has shifted toward natural preservation systems owing to its abundance of bioactive compounds such as the phenolic diterpenes, carnosic acid and carnosol. Research findings indicate that rosemary extracts possess multiple biological functions, including antioxidant, antimicrobial, antifungal, insecticidal, and hepatoprotective activities. These extracts are rich in phenolic compounds and these are actually bioactive compounds, although their effectiveness may vary depending on several intrinsic and extrinsic factors. Despite their health-promoting potential, the application of rosemary extracts in foods can be restricted due to strong sensory attributes such as bitterness, pungency, and intense aroma. To address these challenges, industrial processes have been developed to isolate odorless and colorless antioxidant fractions, thereby broadening the scope of rosemary in food preservation. Consequently, rosemary is emerging as a versatile, natural solution for food preservation and health promotion.

Keywords: Rosemary; phenolic compounds; antioxidant; antimicrobial; *Rosmarinus officinalis*.

INTRODUCTION

Rosmarinus officinalis L., a member of the *Lamiaceae* family and commonly recognized as rosemary, is a perennial aromatic shrub whose Latin name combines *ros* (dew) and *marinus* (sea), a reference to its natural occurrence along coastal regions (Mehmood et al., 2024). The plant is recognized under a wide variety of names depending on geographical and cultural context.

Growing concerns about the health risks linked to synthetic food additives have encouraged the demand for "clean-label" products (Nieto et al., 2011). Consequently, natural plant extracts are gaining attention as safe and multifunctional alternatives, with properties including antioxidant, antidiabetic, antimutagenic, antitoxic, and antimicrobial activities.

A wide variety of herbs and spices contain bioactive molecules capable of counteracting oxidative damage. These include vitamins such as C and E, glutathione, enzymatic antioxidants, and notably phenolic compounds. Certain spice extracts have also demonstrated the ability to prevent lipid peroxidation, thereby improving the stability of unsaturated fats in foods (Hauver et al., 2011). Among the *Lamiaceae*, rosemary, thyme, and sage are particularly well for their strong antioxidative effects. While native to the Mediterranean basin, rosemary is now cultivated globally, with Spain—especially the Murcia region—serving as a central hub for processing and export. In Europe and North America, rosemary is marketed both as a culinary herb and as a natural antioxidant.

Beyond its gastronomic use, rosemary has attracted scientific interest for its pharmacological potential. Extracts have been

Khawaja, A.H., Amir, R.M., Azam, M.T., Latif, A., Samee, A., Razzaq, S., Zahoor, Z., Nasir, M., Anwar, F., Hassan, S. & Saleemi, A. (2025). Phytochemical Extracts and Essential Oils of Rosemary: Exploring Its Antioxidant, Anti-Inflammatory and Nutritional Potentials. *Journal of Food Processing and Nutrition Research*, *2* (2), 139-143.
[Received 22 Jun 2025; Accepted 11 Aug 2025; Published 10 Dec 2025]

Attribution 4.0 International (CC BY 4.0)

linked to hepatoprotective functions, benefits in neurodegenerative conditions such as Alzheimer's disease, and anti-angiogenic activity. Within the food industry, rosemary extracts are widely employed to limit oxidative rancidity and microbial contamination, positioning them as promising replacements for synthetic preservatives (Reblova, 1999). Rosemary, botanically recognized as Salvia rosmarinus (formerly Rosmarinus officinalis L., following an official classification update in the Lamiaceae family), is an evergreen shrub characterized by narrow, needle-like leaves and flowers that may be purple, pink, blue, or occasionally white. Although its current scientific name is Salvia rosmarinus, it is still widely known as R. officinalis. The plant occurs both as upright and trailing forms, reaching heights of 1.2-1.8 meters. Leaves typically measure 2-4 cm in length and 2-5 mm in width, displaying dark green upper surfaces and whitish, hairy undersides. While flowering is seasonal in temperate regions, rosemary can bloom throughout the year in warmer climates (Mekonnen et al., 2017). Lifespans of up to 35 years have been recorded. Closely related species include *Salvia jordani* (formerly *Rosmarinus epicalyx*), which is native to the Iberian Peninsula and the Maghreb.

Phytochemical investigations have identified more than 150 secondary metabolites in rosemary essential oil, including rosmarinic acid, caffeic acid, ursolic acid, camphor, α-pinene, carnosic acid, and carnosol. Camphor alone can constitute 10-20% of the oil composition. Extracts rich in carnosic acid and carnosol have been approved as food antioxidants in several countries. Carnosic acid, an abietane diterpene, occurs naturally in rosemary and common sage (*Salvia officinalis*), accounting for 1.5-2.5% of dried leaves. Together with carnosol, this compound functions as a highly effective antioxidant and is often marketed under the general designation "rosemary extracts"(Zegura et al., 2011). Additionally, rosmarinic acid—whether isolated from plants or chemically synthesized—is applied as a flavoring agent in foods and beverages, as well as in cosmetics and dietary supplements. This review aims to explore the phytochemical constituents of rosemary and evaluate its antioxidant, anti-inflammatory, and nutritional potentials with emphasis on food and health applications (Table 1).

***Composition of Rosemary Extract and Essential Oil*:** Rosemary (*Rosmarinus officinalis* L.) contains several bioactive compounds responsible for its strong antioxidant capacity, particularly cyclic diterpene diphenols such as carnosic acid and carnosol. Additional constituents include rosmanol, epirosmanol, isorosmanol, and methylcarnosate (Khademi Doozakhdarreh et al., 2022). Rosemary essential oil is typically extracted through steam distillation of young shoots and fresh leaves (Sienkiewicz et al., 2013). Its

Table 1. Phytochemical Profile

Topic	Key Findings	Application
Botanical Overview	*Rosmarinus officinalis L.* is a perennial, aromatic shrub originating from the Mediterranean region and now widely cultivated across the globe.	A globally accessible source of bioactive constituents for food, nutraceutical, and health-related uses.
Phytochemical Profile	Comprises more than 150 metabolites, including carnosic acid, carnosol, rosmarinic acid, camphor, α-pinene, and ursolic acid; encompasses both volatile and non-volatile phenolics.	Provides the carnosic acid and carnosol are lipophilic diterpenes responsible for >90% of rosemary's antioxidant activity
Extraction Techniques	Common approaches include steam distillation, solvent-based extraction, supercritical CO_2, and fractionation. Extraction yield and biological activity depend on the method employed.	Method selection influences extract potency, sensory acceptability, and suitability for industrial applications.
Antioxidant Potential	Carnosic acid and carnosol account for the majority of antioxidant activity; they neutralize reactive oxygen species, prevent lipid peroxidation, and enhance fat stability.	Widely utilized in food preservation, dietary supplements, pharmaceuticals, and cosmetic formulations.
Anti-inflammatory Potential	Experimental models demonstrate reductions in pro-inflammatory cytokines (IL-6, TNF-α), edema, and leukocyte migration; limited but encouraging evidence in human studies.	Suggests potential as supportive therapy in chronic inflammation and neurodegenerative conditions.
Clinical & Nutritional Insights	Early investigations indicate beneficial roles in managing obesity, diabetes, osteoarthritis, rheumatic disorders, and neurological protection.	Results are promising but require confirmation through larger, well-designed clinical trials.
Food Industry Applications	Acts as a natural preservative by delaying lipid oxidation and inhibiting microbial growth; already approved as a food-grade antioxidant in several regions.	Offers a clean-label substitute for synthetic preservatives such as BHA, BHT, and propyl gallate.
Constraints	Characterized by strong aroma and flavor; phytochemical composition depends on genotype, growing conditions, and extraction method	Development of deodorized and neutral-colored extracts is necessary for broader consumer appeal.
Future Perspectives	Research priorities include advanced extraction methods, improved stability, dose optimization, and clinical validation.	Potential to expand applications in functional foods, therapeutic formulations, and sustainable preservation strategies.

composition varies significantly depending on geographical location, cultivation conditions, plant age, and extraction method. For instance, some studies identified 1,8-cineole (46.4%), camphor (10-20.%), and α-pinene (11.0%) as the predominant components, while others reported 1,8-cineole (26.5%) and α-pinene (20.1%) as major constituents. Another analysis highlighted camphor (37.6%), 1,8-cineole (10.0%), p-cymene-7-ol (7.8%), and borneol (5.4%) as dominant compounds, emphasizing the high variability of rosemary oil chemistry across studies.

In addition to its volatile fraction, *R. officinalis* is a rich source of non-volatile phenolic compounds, which largely account for its pharmacological and preservative properties. These include phenolic acids, flavonoids, and diterpenoids. Rosmarinic acid, hydroxyhydrocaffeic acid, and related caffeic acid derivatives further enhance antioxidant activity through radical scavenging and metal-chelation mechanisms. These compounds stabilize free radicals by binding transition metals, thereby preventing lipid peroxidation and oxidative stress. Owing to its chemical composition, rosemary oil has been used traditionally as both a culinary flavoring and a natural antimicrobial and antioxidant agent. The therapeutic use of rosemary oil extends to chronic diseases, including diabetes mellitus and inflammatory conditions. Its biological activity is mainly attributed to phenolic constituents, such as caffeic acid, rosmarinic acid, and carnosic acid, which exhibit anti-inflammatory, hepatoprotective, antimicrobial, and antidiabetic effects (Bracco et al., 1981).

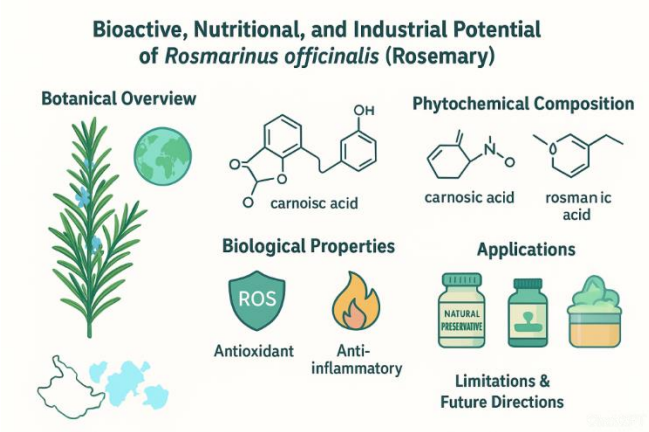

Figure 1. Bioactive, Nutritional, and Industrial Potential of *Rosmarinus officinalis* (Rosemary)

ANTI -INFLAMMATORY PROPERTIES OF ROSEMARY

***Human Studies*:** In a controlled trial, encapsulated rosemary powder (2.8 g/day) was administered orally to 12 individuals for 7 days. Ex vivo analysis demonstrated that serum from treated participants significantly reduced interleukin-6 (IL-6) and tumor necrosis factor-α expression in oxidized LDL-stimulated THP-1 monocytes compared with controls. These findings suggest that rosemary constituents are bioavailable at physiologically relevant concentrations. Notably, no adverse effects were reported during the intervention.

***Animal Studies*:** Rodent models provide additional support for rosemary's anti-inflammatory effects. Oral administration of rosemary essential oil (250-750 mg/kg) 30 minutes before carrageenan injection reduced paw edema with an efficacy comparable to indomethacin (5 mg/kg). Moreover, at 500 mg/kg, the oil reduced pleural exudate volume and suppressed leukocyte infiltration, an effect not observed with indomethacin. The essential oil in this experiment was rich in myrcene (25%), 1,8-cineole (20%), and other terpenes.

Similarly, in mice, rosemary oil containing α-pinene (17%), 1,8-cineole (16%), camphor (28%), and β-myrcene (10%) significantly reduced leukocyte rolling, adhesion, and following carrageenan-induced inflammation. In vitro studies confirmed that rosemary oil (10^{-4}-10^{-2} μL/mL) inhibited leukocyte chemotaxis toward casein, highlighting suppression of leukocyte-endothelial interactions as a key mechanism. Further experiments revealed that a rosemary-derived volatile fraction (43% 1,8-cineole, 41% camphor, 14% limonene) reduced diesel exhaust particle-induced lung inflammation in mice by lowering expression of pro-inflammatory cytokines such as MIP-1α, MCP-1, and keratinocyte chemoattractant, although interleukin-1β remained unaffected. Interestingly, this protective effect occurred independently of oxidative stress pathways. The same extract also reduced airway eosinophilia and IL-13 expression in mice exposed to house dust mites, suggesting potential application in asthma management.

***Clinical Applications of Extracts*:** Human clinical data on rosemary (*Rosmarinus officinalis* L.) are still relatively scarce, but the evidence available so far is encouraging. In one observational investigation, patients with rheumatic disorders received a combination of rosemary extract, reduced iso-α acids from hops, and oleanolic acid at doses of 1320-1760 mg/day for eight weeks. This regimen led to decreased C-reactive protein levels in those who initially presented with elevated values; however, the precise role of rosemary within the formulation could not be confirmed. A separate clinical trial in individuals with osteoarthritis evaluated a similar preparation (600 mg/day for four weeks) and reported improvements in symptom severity. Although such findings suggest therapeutic potential, rosemary extract by itself has not yet undergone extensive clinical assessment. Current knowledge points to its possible use as a supportive treatment in chronic inflammatory conditions, but rigorous studies are needed to clarify its independent effects, optimal dosing, and clinical efficacy. Well-controlled randomized trials remain a priority for future research (Birtic et al., 2015).

***Antioxidants from Rosemary*:** The antioxidant capacity of rosemary extracts depends heavily on how the material is processed, particularly the choice of extraction method and solvent. Various procedures have been reported, including

extractions with vegetable oils or animal fats, mechanical pressing, alkaline water extraction, and the use of organic solvents such as hexane, diethyl ether, chloroform, ethanol, methanol, dioxane, and ethylene dichloride (Habtemariam, 2016).

In many protocols, the crude extract is first washed with water and the solvent is removed. For further purification, it may be dissolved in methanol and treated with activated carbon at 60 °C for 15 minutes. The antioxidant molecules in rosemary are generally smaller than triglycerides present in carrier oils like peanut oil, which enables their separation by molecular distillation using falling-film or centrifugal techniques (Djenné, 2002). Today, dried rosemary leaves are most often used as the starting material, and modern extraction approaches commonly incorporate partial deodorization or decolorization to enhance the sensory qualities of the extract. Reported extraction yields vary widely, from about 2% to 26%, depending on the raw material and the method applied (Nieto et al., 2010).

***Mechanisms of Anti-Inflammatory and Antioxidant Activity in Rosemary*:** Compounds derived from *Rosmarinus officinalis* L. demonstrate both antioxidant and anti-inflammatory properties through diverse biochemical mechanisms. A key contributor is the presence of isoprenoid quinones, which function as chain-breaking molecules that intercept free radicals and act as chelators of reactive oxygen species (ROS). In addition, phenolic constituents in rosemary extracts serve as primary antioxidants by reacting with lipid and hydroxyl radicals, converting them into more stable, less harmful derivatives. Among these, carnosic acid and carnosol have been identified as particularly effective radical scavengers. Their activity in suppressing membrane lipid peroxidation surpasses that of commonly used synthetic antioxidants, including butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and propyl gallate (Aguilar et al., 2008).

The antioxidant capacity of rosemary has been widely investigated using different extraction solvents, with clear evidence linking chemical structure to bioactivity. Carnosic acid and carnosol together account for nearly 90% of the antioxidant activity attributed to rosemary. Both compounds inhibit lipid peroxidation in microsomal and liposomal systems, neutralize peroxyl radicals such as CCl_3O_2, reduce cytochrome c, and effectively scavenge hydroxyl radicals. Carnosic acid also demonstrates additional versatility by scavenging hydrogen peroxide (H_2O_2) and functioning as a substrate for peroxidase systems, thereby amplifying its protective effects. The efficiency of rosemary's antioxidant action is further influenced by the stage of plant development. Studies have shown that accumulation of polyphenols—including rosmarinic acid, hesperidin, and carnosol—during the fruiting phase significantly enhances the antioxidant potency of rosemary extracts. These findings emphasize the combined influence of phytochemical composition and growth stage on the biological activity of rosemary (Banjaw et al., 2024).

***Conclusions*:** Lipid oxidation remains a significant concern for both consumers and the scientific community, as it contributes to the development of various health problems such as cardiovascular disease, cancer, ischemia, and degenerative disorders associated with aging. Extracts and essential oils derived from *Rosmarinus officinalis* (rosemary) have demonstrated strong potential in reducing oxidative stress by inhibiting lipid peroxidation in foods as well as in biological systems.

The antioxidant and antimicrobial efficacy of rosemary is not fixed but varies according to multiple factors, including the stage of plant maturity, extraction technique, solvent used, concentration of bioactive molecules, interactions with other compounds, and the presence of inhibitors. By optimizing these conditions, rosemary extracts can be effectively applied in diverse food systems—particularly in products such as meats, edible oils, and dressings—where they improve stability, extend shelf life, and preserve quality. In addition to food preservation, rosemary extracts show promise in nutraceuticals, pharmaceuticals, and functional foods due to their rich phytochemical profile. Their affordability, broad availability, and safety profile make them highly suitable for industrial applications. Extracts enriched in phenolic compounds are especially valuable, highlighting rosemary as a sustainable and natural alternative to synthetic preservatives and additives in both food technology and health-related sectors.

***Acknowledgement*:** The authors would like to express their sincere gratitude to Institute of food and Nutritional Sciences PMAS-AAUR for providing academic and technical support during the preparation of this review. The constructive comments and guidance from Dr. Rai Muhammad Amir are also deeply appreciated. This work received no external funding

***CRediT Author Statement*:** *Aqsa Hassan Khawaja:* Conceptualization, literature review, data curation**,** original draft preparation, and correspondence. Rai Muhammad Amir: Supervision, critical review, and validation. Muhammad Tauseef Azam: Methodology input, data interpretation, and manuscript review. Asia Latif: Literature screening, data organization, and editing. Abdus Samee**:** Visualization, figure preparation, and technical support. Salma Razzaq: Writing support and reference management. Zunaira Zahoor**:** Data compilation and proofreading**.** Mawara Nasir: Formatting and language editing**.** Fareeha Anwar: Critical revision and quality control. Shazmina Hassan: Conceptual support and scientific review. Hjara Afzal Saleemi: Final review and approval of the manuscript.

***Conflict of interest*:** The authors declare that there is no conflict of interest regarding the publication of this paper.

***Ethical statement*:** This article is a review and does not involve any studies with human participants or animals conducted by the authors. Therefore, ethical approval and informed consent were not required.

***Availability of data*:** No new data were generated or analyzed in this study. Data sharing is not applicable to this article.

***Consent to participate*:** Not applicable. This study did not involve human participants or animals; therefore, consent to participate was not required.

***Informed consent*:** Not applicable. This study did not involve human participants or animals; hence, informed consent was not required.

***Consent for publication*:** Not applicable. This study does not include any individual person's data, images, or personal information; therefore, consent for publication is not required.

SDGs addressed: Good Health and Well-being, Responsible Consumption and Production

***Policy referred*:** National Food Security Policy of Pakistan, National Nutrition Policy of Pakistan, National Climate Change Policy, Pakistan Vision 2025, National Food Safety Policy.

Publisher's note: All claims stated in this article are exclusively those of the authors and do not necessarily represent those of their affiliated organizations or those of the publisher, the editors, and the reviewers. Any product that may be evaluated/assessed in this article or claimed by its manufacturer is not guaranteed or endorsed by the publisher/editors.

REFERENCES

Mehmood, A., Naveed, K., Ayub, Q., Alamri, S., Siddiqui, M. H., Wu, C., & Fahad, S. (2021). Moringa leaf extract as a biostimulant: Enhancing yield and quality of black cumin oil. *Scientific Reports*, 11(1), 24217.

Nieto, G., Bañon, S., & Garrido, M. D. (2012). Effect of thyme leaf distillate supplementation in ewe diets on lamb meat quality. *Animal*, 6, 2048-2056.

Huvaere, K., & Skibsted, L. H. (2011). Antioxidant activity of rosemary and thyme by-products: Synergistic effects with added antioxidants in a liposome model system. *European Food Research and Technology*, 233, 11-18.

Mekonnen, M., & Manahile, B. (2017). Yield losses in rosemary and sage caused by *Fusarium oxysporum*. *African Journal of Agricultural Research*, 12(19), 1669-1673.

Reblova, Z., Kudrnova, J., Trojakova, L., & Pokorny, J. (1999). Stabilization of frying oils with rosemary extracts during deep-fat frying. *Journal of Food Lipids*, 6, 13-23.

Zegura, B., Dobnik, D., Niderl, M. H., & Filipi, M. (2011). Antioxidant and antigenotoxic effects of rosemary extracts in *Salmonella Typhimurium* TA98 and HepG2 cells. *Environmental Toxicology and Pharmacology*, 32, 296-305.

Khademi Doozakhdarreh, S. F., Khorshidi, J., & Morshedloo, M. R. (2022). Influence of harvesting time and drying method on essential oil composition, phenolic content, and antioxidant activity of rosemary.

Habtemariam, S. (2016). Therapeutic potential of rosemary diterpenes in Alzheimer's disease. *Evidence-Based Complementary and Alternative Medicine*, 2016, 2680409.

Djenane, D., Sánchez-Escalante, A., Beltrán, J. A., & Roncalés, P. (2002). Effect of α-tocopherol, taurine, and rosemary in combination with vitamin C on oxidative stability of beef steaks stored under modified atmosphere. *Food Chemistry*, 76, 407-415.

Aguilar, F., Autrup, H., Barlow, S., Castle, L., Crebelli, R., Dekant, W., Engel, K. H., Gontard, N., Gott, D., Grilli, S., et al. (2008). Scientific opinion on the use of rosemary extracts as a food additive. *EFSA Journal*, 721, 1-29.

Banjaw, D. T., Megersa, H. G., Abewoy, D., & Lema, D. T. (2024). Recent classification, characteristics, economic significance, and cultivation of rosemary (*Rosmarinus officinalis* L.). *International Journal of Scientific Research in Engineering Development*, 7(1), 157-166.

Birtic, S., Dussort, P., Pierre, F. X., Bily, A. C., & Roller, M. (2015). Carnosic acid: A major antioxidant from rosemary. *Phytochemistry*, 115, 9-19.

Bracco, U., Loliger, J., & Viret, J. L. (1981). Production and application of natural antioxidants. *Journal of the American Oil Chemists' Society*, 58, 686-690.